



Moderator Exclusion

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Presentation Outline

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Introduction to Moderator Exclusion

- NRC Safety Goal: Ensure adequate protection of public health and safety and the environment.
- Strategic Outcomes for Safety:
 - Prevent the occurrence of any inadvertent criticality events.
 - Prevent the occurrence of any acute radiation exposures resulting in fatalities.
- Moderator Exclusion: preventing moderator (e.g., water) from entering a package in order to maintain subcriticality (not a definition in 10 CFR 71.4).

Regulatory Requirements

- **71.55(b):** Outlines the requirements for design, construction and content limit. Requires subcriticality if “*water were to leak into the containment system*” with maximum material reactivity under: 1) the most reactive credible configuration, 2) moderation to the most credible extent, and 3) full reflection by water on all sides.
- **71.55(c):** Allows Commission possible (“*may*”) exceptions to the requirements of 71.55(b).
- **71.55(d):** For Normal conditions of transport (NCT), requires:
 - 1) subcriticality;
 - 2) the geometric form of the package contents would not be substantially altered. (*content requirement*)

Regulatory Requirements

- 3) there would be no leakage of water into the containment system unless it has been assumed that moderation is present to such an extent as to cause maximum reactivity.
 - 4) there will be no substantial reduction in the effectiveness of the packaging. (*Packaging requirement*)
- **71.55(e):** For Hypothetical accident conditions (HAC) the package is required to be subcritical. For this determination, it must be assumed that:
 - 1) The fissile material is in the most reactive credible configuration;
 - 2) **Water moderation** occurs to the most reactive credible extent **consistent with the damaged condition of the package** and the chemical and physical form of the contents; and
 - 3) There is full reflection by water on all sides, as close as is consistent with the damaged condition of the package.

Recent History of Moderator Exclusion

- 2003: ISG-19, Revision 0 [1]
 - Provided guidance to staff on reviewing an acceptable approach using moderator exclusion for meeting 71.55(e) requirements (i.e., after regulatory Hypothetical Accident Conditions).
- 2005: EPRI Report “Options for Pursuing Moderator Exclusion for Application to Spent-Fuel Transportation Packages” [2] suggested:
 - “(1) an interpretation of §71.55 and development of guidance to allow moderator exclusion under certain conditions, such as a recognition of design features that result in moderator intrusion being not “credible” under both normal and accident conditions... or
 - (2) rulemaking to change §71.55 to remove the “exception” language.”

Recent History of Moderator Exclusion

- 2007: SECY-07-0185 Moderator Exclusion in Transportation Packages [3]

NRC Staff presented 3 options to the Commission on Moderator Exclusion:

- Option 1: Moderator Exclusion for HAC (per ISG-19) AND limited-shipment use of the **71.55(c) exception**.
 - Option 2: Moderator Exclusion in spent fuel cask-design approvals under 10 CFR 71.55(c), **as justified by additional risk information**.
 - Option 3 (*Staff-recommended option*): **Rulemaking** to codify the acceptable uses of Moderator Exclusion for spent fuel transportation packages, while continuing current staff practices in the interim.
- Important note – the Option 3 main recommendation was codification of Moderator Exclusion as design basis, unlike ISG-19, which addresses subcriticality requirements after HAC.

Recent History of Moderator Exclusion

- 2007: Commission Vote on Moderator Exclusion in Transportation Packages [4]
 - The Commission *unanimously disapproved* staff recommendation.
 - The Commission clarified the desire not to have exceptions as a preferred approach to licensing, regulatory flexibility notwithstanding.
 - The Commission did “*not believe licensees may generically argue that this requirement can be eliminated from a risk perspective*”, found improbability “*not... a sufficient basis... to eliminate... an effective safety assumption*” and encouraged “*licensees to develop the necessary technical basis to provide a more realistic description of fuel composition*” (i.e., burnup credit).

Options for Moderator Exclusion - Today

- Moderator exclusion for HAC is still valid under the current regulatory framework.
- *What is a possible path that could meet regulatory intent?*

Options for Moderator Exclusion - Today

- Baseline criticality safety configuration - compliance with 71.55(b).
- Double containment
 - At least two (2) redundant barriers
 - Elastic closure performance
 - Assurance of leaktight containments
 - Possible 3-barrier “insert” system (reference: Idaho Report, 2011 [5])

Options for Moderator Exclusion - Today

Demonstration process:

- Qualification of impact limiter performance and obtaining accelerations (g-loads) from full or scale model 30-ft drop tests.
- Benchmark of fully dynamic finite element analysis with obtained data. Dynamic finite element analyses that demonstrate adequate structural performance of the package for 30-ft drop configurations.

Options for Moderator Exclusion - Today

- For evaluation of overpack bolt closures, the following conditions should be satisfied:
 - The bolts behave elastically and are analyzed according to the recommendations of NUREG-6007.
 - The mating surfaces surrounding the closure have returned to their original configuration at the end of the 30-ft drop simulations.
 - The minimum seal compression per manufacturer's recommendation is maintained at all times during the dynamic finite element drop simulations.

Options for Moderator Exclusion - Today

- Structural analysis demonstrating adequate behavior (e.g., below yield) of canister welded closure under NCT and HAC.
- Consideration of potential surface scratch/mishandle, such as removing a portion of canister thickness for structural considerations.
- In addition to the transportation package containment system, the canister would need to meet 10 CFR 71.61 requirements (water pressure).

Options for Moderator Exclusion - Today

- The preceding considerations are currently being explored at NRC as a basis for a revision to ISG-19.
- There are still some challenges and related topics that should be addressed.

Challenges and Considerations

- Compliance with 71.55(d)(2) (for High-Burnup Fuel):

“the geometric form of the package contents would not be substantially altered” (for NCT)

- Lack of material properties presents the problem of characterizing fuel behavior.
- How will thermal limits, shielding limits, materials requirements (i.e., chemical or galvanic reactions), etc., be demonstrated?

Challenges and Considerations

- Compliance with 71.55(e)(2):
 - *“Water moderation occurs to the most reactive credible extent consistent with the damaged condition of the package and the chemical and physical form of the contents;”*
- If moderator is excluded, there should be justification that the physical form of the contents has inconsequential effects on criticality; or assumed bounding reconfigurations for the criticality analyses.

Challenges and Considerations

- Compliance with 71.55(e)(2) (cont.):
 - If the physical form of the contents is not included in the justification, bounding cases and considerations should be provided in order to meet temperature, dosage, structural and containment concerns (e.g., effect of content impacting the lid, thermal/dosage effects of potential accumulation of material, etc.)

Challenges and Considerations

- Retrievability
 - What will be the requirements for handling in the context of ultimate disposal, or post-storage transport, or post-transport storage?
 - Compliance with future requirements cannot be guaranteed.
- Burnup Credit
 - Has this avenue been exhausted?

Summary

- Moderator exclusion for HAC is still valid under the current regulatory framework.
- There are still some regulatory challenges for Moderator Exclusion as High-Burnup Fuel transport option.
- Consideration should be given to other important topics such as retrievability, post-storage transport, post-transport storage, and fuel handling requirements and/or disposal by receiving facility.

- 1) U.S. Nuclear Regulatory Commission, “Moderator Exclusion Under Hypothetical Accident Conditions and Demonstrating Subcriticality of Spent Fuel under the Requirements of 10 CFR 71.55(e),” Division of Spent Fuel Storage and Transportation Interim Staff Guidance – 19, Rev. 0, May 2, 2003. ADAMS # ML031250639.
- 2) Electric Power Research Institute, “Options for Pursuing Moderator Exclusion for Application to Spent-Fuel Transportation Packages,” December 2005. 1011815.
- 3) U.S. Nuclear Regulatory Commission, “SECY-07-0185: Moderator Exclusion in Transportation Packages,” October 22, 2007. ADAMS # ML072190681.

- 4) U.S. Nuclear Regulatory Commission, “Commission Voting Record on SECY-07-0185, Moderator Exclusion in Transportation Packages,” December 18, 2007. ADAMS # ML073520738.
- 5) Idaho National Laboratory, “Transportation Task Report on Achieving Moderator Exclusion and Supporting Standardized Transportation,” September 2011. INL/EXT-11-22559.